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cover story

A Tight Fit

The elements of this month's cover story go together like hand and glove. Part 1 looks at spindle maintenance and repair, while Part 2 explains the three options for repairing tapered toolholders.

Part 1: Keeping the Machine Spindle Running Round

▸ BY WALTER AMMERMAN JR.

A great deal of attention is paid to developing faster and more accurate tooling and machine tools. But what about the machine's spindle? No matter how fast and accurate the aforementioned elements of the metalcutting process are, a machine with a worn spindle won't produce good parts.

Furthermore, wear to the spindle taper is inevitable because automatic toolchangers (ATC) are constantly taking toolholders in and out of the spindle socket. A worn spindle taper can cause runout, tool chatter, endmills that cut oversized slots, boring bars that don't consistently cut to size and excessive wear on inserts due to uneven chip loads. All these side effects of a worn spindle taper waste time and money.

The solution is to properly maintain the machine spindle. First, though, let's look at the causes of spindle-taper degradation.

Identity Crisis

It's a popular myth that a bad spindle taper causes out-of-round bores. But a boring bar cuts along the centerline of the spindle, so a bad taper will cause the hole to be oversized or undersized, but it won't create an out-of-round condition.

The common causes of an out-of-round condition are movement in the mechanical axis, loose spindle bearings and improper grinding of the spacers between the spindle bearings. Nonetheless, many maintenance people tend to look at the spindle bearings or the fixtures when an out-of-round problem occurs, when they should first check the fit of the toolholder in the spindle taper.

Alan Richter

Greg Schurky, a grinding technician for Spindle Grinding Service, regrinds a spindle that was damaged due to a spun toolholder.

Bellmouthing, a common type of wear pattern in a spindle taper, is caused by the constant pounding of the toolholder on the large end of the spindle taper. Material from the spindle taper is "swedged" (or mechanically moved) out of the taper, creating a bellmouth shape. Once this wear pattern begins to allow toolholder movement within the spindle, the problem will progressively worsen.

A sure sign of bellmouthing is the appearance of a copper- or rust-colored residue on the spindle or tool taper. This residue is "fretted" metal.

Fretting is a form of metal wear caused by vibration, in this case between the ill-fitting toolholder and the spindle taper. The rust-colored residue is actually minute particles of oxidized metal fretted away from both the toolholder and the spindle taper. Fretting creates shallow pits in the respective tapers, which eventually leads to imprecise metalcutting.

If bellmouthing is suspected, there are two direct methods for detecting it. The first requires mounting an indicator on the table and then sweeping the indicator needle across the center of the spindle face using an X-axis movement. A "hump" will be apparent on the innermost diameter of the spindle face if there's a bellmouthing condition. The hump consists of the metal that was swedged out of the taper and onto the spindle face. It reduces the supporting force on the large end of the taper, severely reducing the rigidity of the clamping system.

The second method is bluing, the most common technique used by machinists for marking metal surfaces. Simply cover a good toolholder or taper gage with the blue-colored coating (i.e., Hi-Spot Blue, No. 107, nondying) and clamp it into the toolholder. Then remove the toolholder and check the "bearing" surface. (The bearing surface refers to the percentage of contact between the toolholder and the spindle taper.) A bearing surface of about 60 percent means that it is time to take corrective action, before the situation deteriorates to the point that the machine needs to be repaired.

If the bluing indicates an acceptable fit, check the tool-retention system. The simplest test involves prying the toolholder away from the spindle taper by inserting a pry bar between the toolholder flange and the spindle face. If it feels abnormally loose, then the tool-retention system needs to be repaired.


A. Richter

A taper gage is blued-up to determine the bearing surface.

Another sign of a spindle-taper problem may come directly from the machine operator. The repeatability of single-point machining is noticeably affected when the taper is out of tolerance. So if an operator is struggling to maintain bore sizes, for example, have him blue-up a toolholder and check its taper bearing.

An Ounce of Prevention

To prevent downtime, the spindle taper should be cleaned periodically with a specialized taper socket cleaning tool or a soft rag. Be sure, though, to clean the entire length of the taper to remove all the dirt and chips.

After cleaning, a retention-force gage should be used to check the toolholding power of the spindle. One end of a retention-force gage is shaped like a standard-taper toolholder. The device is equipped with an internal strain gage that measures the holding force generated when the holder/retention knob assembly is pulled into the spindle taper. On a typical machine tool, the clamping force ranges between 2,000 and 4,000

Part 2: Options for Repairing Tapered Toolholders

▶ BY PAT HJELM

The accuracy and repeatability of the locating surfaces on a tapered-shank toolholder are vital to the life and performance of a cutting tool.

There are two critical components to ensuring optimal toolholder performance. The tapered shank must always remain in complete contact with the matching taper of the spindle throughout the machine cycle. If the contact is not complete, the tapers of both the spindle and holder may be damaged. It is also necessary that the tapered holder run true, or concentric, to the spindle taper—within 0.001".

There are three ways to repair a toolholder taper. The lowest-cost option is to simply regrind the taper, cleaning up pits and scars that distort the holder's fit and concentricity. No material is added to the taper so the procedure is inexpensive, costing only $30 to $60 per toolholder. But the gage-line tolerance must be maintained, meaning that there is a limit to the amount of material that can be removed from the taper before the toolholder bottoms out against the spindle nose. This option is only feasible when the toolholder taper damage is very minor.

The most popular method for repairing a toolholder taper is to weld a steel-based material onto the damaged areas of the taper and then regrind it to the original manufacturer's specifications. Toolholders that undergo this treatment normally have deep gouges or indentations that either prevent the taper from seating inside the spindle and/or create a great deal of runout. This type of repair is slightly more expensive than a straight regrind, averaging $60 to $100 for each holder. But it's still an economical choice if the holder was custom-made and/or expensive.

The third repair option requires grinding the taper, applying a hard-chrome plating and then regrinding the entire taper again. This is the most expensive process, short of replacing the holder, but it provides a flawless surface finish that possesses great strength. At a cost of $200 to $300 per holder, this option is generally only appropriate for complex and very expensive tooling, such as integral-shank tooling. The taper's maximum damage can only be 0.030" to 0.040" deep to avoid adhesion problems when applying the hard-chrome plating. If too much hard chrome is applied, flakes and blisters can appear that could prevent an effective repair.

Finally, it's a good idea to periodically have a qualified professional make sure the repaired tapers meets OEM specifications, especially if part tolerances are routinely held very close to the maximum capability of the machine and tooling system.

About the Author

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lbs., but can be as low as 800 lbs. or as high as 8,500 lbs., depending on the application. Then, bluing should be performed again to check the percentage of contact between the toolholder and spindle taper. These activities should be a part of any preventative-maintenance program.

Another thing that a shop needs to monitor is the machine tool's hydraulic system to ensure that it provides sufficient knockout pressure. The knockout pressure is the amount of force needed to eject the toolholder from the spindle taper. Hydraulic pressure typically releases the spring pressure that closes a collet around the retention knob of the toolholder, securing it within the spindle taper. If the clamping force of a spindle is specified as 4,000 lbs., then the knockout force must equal at least 4,000 lbs. to assure that the toolholder will be ejected during a tool change.

This may sound elementary, but my company, which specializes in in-machine spindle regrinding, averages one stuck-tool call a day where we find that the knockout force is insufficient and caused by a hydraulic problem.

The toolholder must be cleared from the taper by 0.015" to 0.020" to consistently allow the ATC arm to remove it from the spindle. Tool knockout distance can be checked quickly and easily with an indicator with a 1" travel. Place a toolholder in the spindle and manually lock it. Then hit the manual unlock button on the control. The toolholder should move and hold position anywhere from 0.015" to 0.020". The drawbar stroke should be adjusted if the toolholder is positioned out of this range.

Crash Course

The ANSI B5.10 spindle taper specification is 3.500"/ft. But I've found that most machine tool builders make the small end of the taper a little "more open." This gives the toolholder room to move toward the back of the spindle as the large end of the spindle taper wears. As a result, the toolholder remains tightly clamped in the front end of the spindle for a longer period of time, increasing the life of the spindle taper.

Despite the best PM practices and methods for extending spindle life, spindles sometimes fail and need to be repaired.

If the spindle taper only needs minor repair, some maintenance people use hand-held burr grinders to do the job. I don't recommend it. Two potential problems are likely to arise when trying to grind metal from the spindle taper with a hand grinder.

Spindle Mate Inc.

A spindle-taper cleaner, like the SpinLMate, removes materials that build up in a spindle over time.

First, holes can be ground in the spindle taper. Second, if the toolholder also has been pushed to one side while spinning, the metal from the holder will not be distributed evenly on the spindle taper's surface. Thus, hand grinding may make a bad situation worse by inadvertently creating an unacceptable amount of runout into the taper.

If the spindle taper is properly reground, a minimum of stock is removed—generally between 0.002" and 0.004"—depending on the severity of the crash and how much the spindle became "egged" or distorted out of round.

The spindles in high-speed machining centers require higher-precision regrinding. When spindle speed exceeds 10,000 rpm, the large end of the spindle taper expands. If the small end of the taper is more open, the holder can move 0.0002" to 0.0004" deeper in the spindle as the speed rises above 10,000 rpm. When this happens, the toolholder often becomes stuck.

High-speed spindles also seem to exert less side pressure than low-speed spindles, which means that the taper match can be reground much closer.

In a typical new machine tool, the flange is located 0.060" to 0.125" from the gage line. A routine spindle regrind causes the gage line to move 0.010" or less. The Z-axis home position must then be zero-offset for the difference before the machine is ready to go.

In or Out

A spindle-taper regrinding job can be performed with the spindle on or off the machine. To ensure an effective in-machine regrind, proper grinder setup is critical. So are having the needed equipment and a solid understanding of how to operate the grinder. A few major manufacturers have the equipment and expertise to properly perform in-machine spindle regrinding in-house, but since the procedure is required infrequently, economics usually dictate outsourcing the service at virtually all other shops.

Regrinding the spindle in place has several practical advantages. Whenever a spindle bearing pack is disassembled, a complete replacement of the bearing set is recommended to ensure that accuracy will be maintained after the machine is reassembled. Bearing sets can cost anywhere from $300 to $2,000, depending on the size and class of bearings recommended by the builder.

In addition, removing a spindle means disconnecting or disassembling clutches, lubrication lines and mechanisms in the gearbox—all potential sources of problems during re-assembly.

The final advantage is time. An in-machine regrind can usually be accomplished in less than a day. It can take several weeks for a spindle sent to a regrind service to be returned.

About the Author

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